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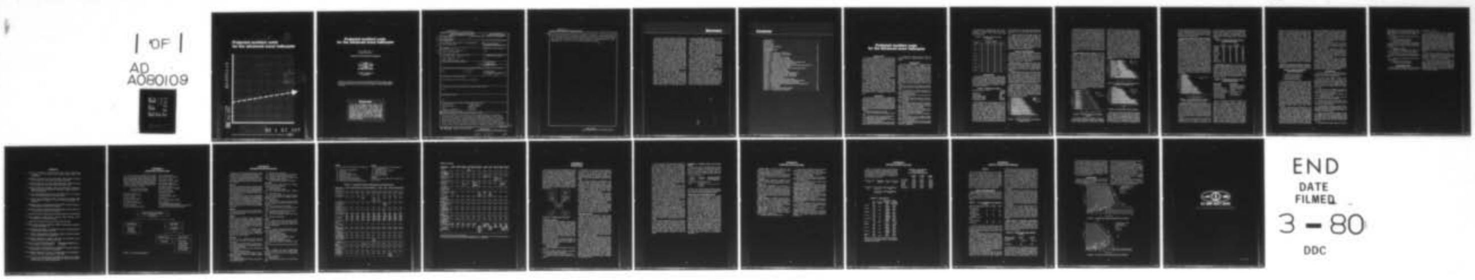

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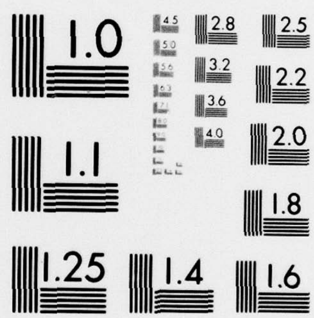
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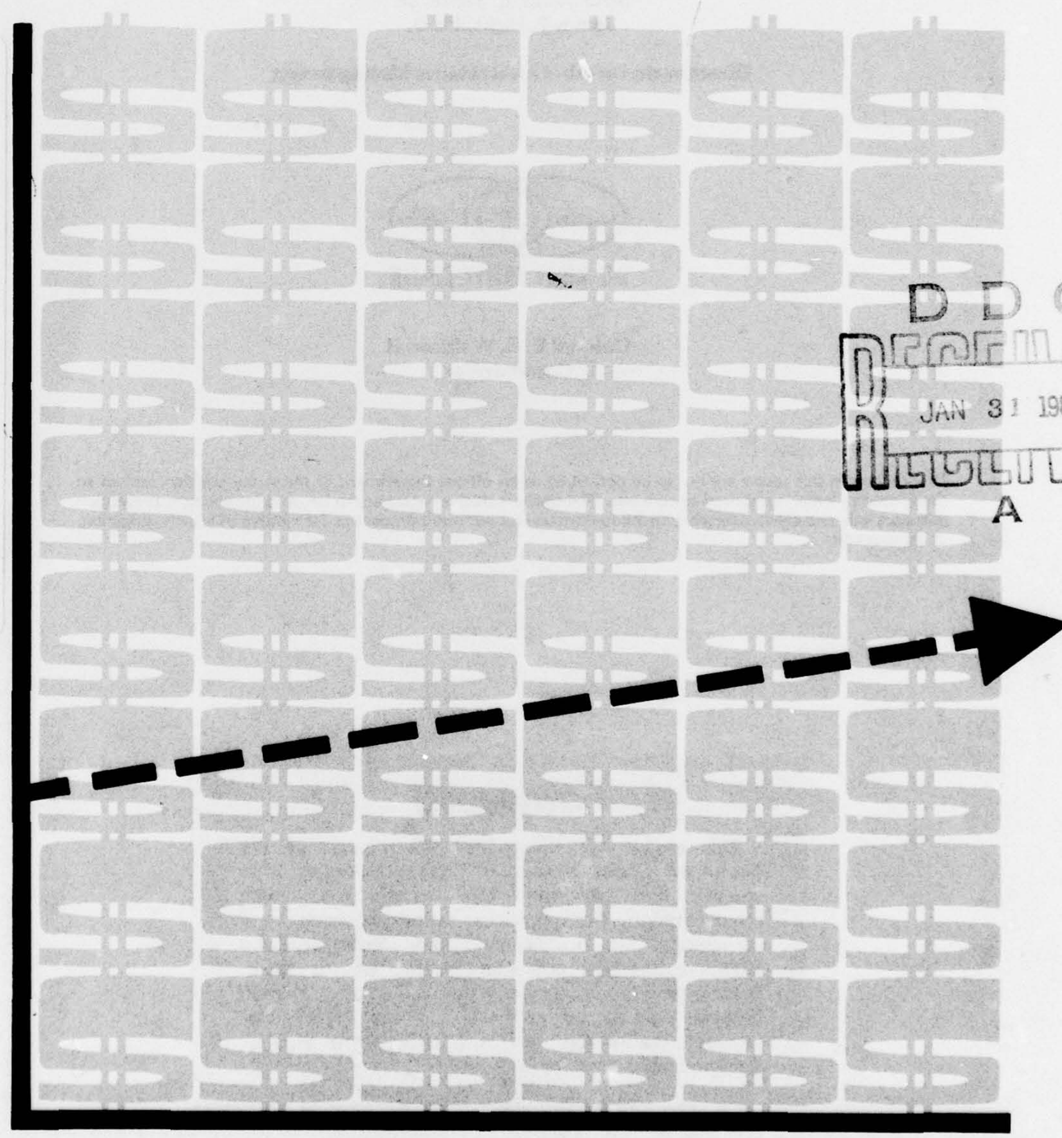

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UNITED STATES ARMY SAFETY CENTER TECHNICAL REPORT ■ TR 80-1 ■ OCTOBER 1979

Projected accident costs for the advanced scout helicopter

by
MAJ James E. Jenks, Jr.
James E. Hicks, Ph.D.

Directorate for Aircraft Systems Management

U.S. ARMY SAFETY CENTER

Colonel E. E. Waldron II
Commander

Foreword

This study was initiated at the request of the Advanced Scout Helicopter Project Manager. The analysis was performed by a study team with representation from various Army agencies and commands. The U.S. Army Safety Center provided technical direction and management of the team. Participating agencies were the U.S. Army Human Engineering Laboratory, the U.S. Army Aeromedical Research Laboratory, and the U.S. Army Applied Technology Laboratory.

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This is the report of an analysis of the economic benefits of providing crashworthiness and other safety-related design improvements within future Army scout helicopters. The analysis was performed for use by the Advanced Scout Helicopter Project Manager (PM-ASH). The analysis baseline was all OH-58A major and minor aircraft accidents from January 1972 through December 1978. Projections are made for 11 candidate aircraft designs which may have potential use in the scout helicopter role as defined by PM-ASH. Accident (cont'd)

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cont. rates and losses are derived for each candidate aircraft. Losses are projected for a 20-year period of peacetime operation. Projections are derived based on each candidate's design features and the effectiveness of these features under the particular conditions in each OH-58A accident. Recommendations are made regarding use of this data in an ASH development program.

Summary

This report contains the results of an analysis of the effectiveness of proposed advanced scout helicopter candidate design features on aircraft projected accident costs. The analysis was performed to provide information for use by the Advanced Scout Helicopter Project Manager (PM-ASH). Aircraft studied were the OH-58C, OH-58D, OH-58E, OH-1 (nose mounted sight), OH-1 (mast mounted sight), OH-64, A-129, AS-350, ASH (new development aircraft, twin engine, with side-by-side seating), ASH (twin engine, with tandem seating), and the ASH (single engine, with side-by-side seating).

The analysis took as its baseline all major OH-58A aircraft accidents from January 1972 through December 1978. These accidents were analyzed in detail by a study group formed by representatives from various Army agencies. This group determined the relative benefits of increased levels of crashworthiness and other flight safety design features. Major accident rates and losses due to accidents were then projected for each of the candidates. The accident losses were projected over a 20-year period of peacetime operation and included both personnel losses and aircraft damage.

The results indicate that the candidate with the lowest accident rate would be the ASH twin engine designs. These aircraft also had a substantially lower accident cost ($115 million) relative to comparable aircraft. This was due to their lower accident rate and increased crashworthiness features outweighing the effects of their increased acquisition cost. The lowest accident cost candidate was determined to be the OH-58C ($108.5 million). The most costly aircraft from an accident standpoint would be the OH-1 (nose mounted sight) candidate ($352.9 million).

The two design factors having the greatest impact in reducing accidents were the twin engine and wire cutter designs. The economic influence under peacetime conditions of twin engine design is reflected in a $27.5 million reduction in life cycle cost between the ASH twin and ASH single engine designs. The wire cutters reduced the life cycle cost of the ASH twin by $25 million in comparison to the A-129. These economic benefits would be increased several fold for operation under tactical or tactical-training conditions.

The primary accident cause factor (80%) was human error. A substantial but unquantified portion of these mishaps were contributed to by poor man/machine integration within the mission environment. Substantial reductions in accidents could be accrued by reducing this man/machine interface problem. It is recommended that previous human factors research on the scout mission be updated using the present ASH candidate designs and mission scenarios.

Accident losses constitute a significant portion of total life cycle costs. The analysis concludes that crashworthiness and other aircraft design features can substantially reduce these losses. It is recommended that the results of this analysis be used in further concept studies and ASH System Acquisition Review Council proceedings. It is further recommended that a follow-on accident study be performed as an adjunct to any future government competitive testing and source selection and evaluation of ASH prototype designs.

Contents

Projected accident costs for the advanced scout helicopter

INTRODUCTION

The Program Manager for the Advanced Scout Helicopter (PM-ASH) requested that the United States Army Safety Center update a previous study (reference 1) of Life Cycle Accident Costs for the Advanced Scout Helicopter. In response to this request (reference 2), an accident analysis team was convened at Fort Rucker, Alabama. Participation was provided by the U.S. Army Aeromedical Research Laboratory (USAARL), the U.S. Army Human Engineering Laboratory (USAHEL), and the Applied Technology Laboratory of the U.S. Army Research & Technology Laboratories. A detailed listing of the group participants and areas of expertise is provided in Appendix A. USASC provided technical direction and management of this study team.

The study team assessed the 20-year accident costs of 11 ASH candidate designs provided by PM-ASH. The projected life cycle accident costs for these candidates were derived from a consideration of flight safety and crashworthiness design features. The candidates studied were chosen by the Department of the Army Special Study Group for ASH as viable alternatives to perform the advanced scout mission. The analysis of these 11 candidates is provided in this report.

OBJECTIVES

The overall goal of the study was to establish the expected economic losses due to aircraft accidents for a wide range of aircraft, which may have potential for use in the scout helicopter role as defined by the PM-ASH. The relative magnitude of these losses is an indication of the influence of crashworthiness and flight safety design features in the various aircraft designs. Accident losses were calculated for a 20-year period of *peacetime* operation.

The specific objectives were as follows:

(1) Determine candidate aircraft projected accident rates.

(2) Determine the mean cost per accident (personnel and equipment) for each candidate aircraft.

(3) Determine the economic losses due to accidents over the total period of operation.

(4) Determine the projected attrition rate (hardware damage greater than 50%) for each candidate aircraft.

(5) Identify critical design features that have the greatest influence in reducing accident rates and severity.

ASSUMPTIONS

The study team evaluated 11 candidate aircraft designs. A description of each candidate aircraft is contained in Appendix B. Several candidate designs were rudimentary with only conceptual descriptions and basic documentation available. Based upon these early stages of the designs, assumptions were made concerning certain design features, as shown in Appendix B. The study also addressed the various fleet mixes proposed by the ASH Special Study Group. These fleet mixes consisted of a homogeneous fleet of candidates or a mix of high performance with low performance (HIGH-LOW mix) aircraft. The total scout fleet of either of these alternatives would be 1,472 aircraft.

Major study assumptions that affected all candidate aircraft were provided by the ASH-PM (reference 3) as follows:

(1) The baseline for the analysis was major and minor aircraft accidents occurring to OH-58A aircraft during *peacetime* operations.

(2) Losses were projected for a 20-year period of *peacetime* operation.

(3) Projections included both personnel (crewmember) and materiel losses from all major and minor aircraft accidents.

(4) Losses were projected in constant FY 80 dollars.

(5) The only safety improvements to be considered were those designed into the candidate aircraft as described in official system documentation.

(6) A two-man crew of a rated aviator and an enlisted flight crewmember/observer was assumed for all candidate aircraft with the exceptions:

(a) Ferry and maintenance test flights consisted of a rated aviator only.

(b) Training missions in which the baseline OH-58A had a pilot and instructor pilot would consist of a similar crew for all candidate aircraft.

(7) The only candidate aircraft with wire cutters were the new development aircraft, as further described in table B-1, Appendix B.

(8) Losses were calculated based upon current estimates of aircraft acquisition cost, fleet size (as summarized in table 1) and flying hours (240 hours/aircraft/year).

TABLE 1.—Candidate Aircraft Fleet Costs, FY 80 Dollars

CANDIDATE AIRCRAFT	QUANTITY	AIRCRAFT REPLACEMENT (MILLIONS)	MISSION EQUIPMENT (MILLIONS)	TOTAL REPLACEMENT
OH-58C	1,129 1,472	0.230 0.243	0.059 0.057	0.289 0.300
OH-58D	1,129 1,472	0.533 0.404	0.288 0.277	0.821 0.681
OH-58E	1,129 1,472	0.828 0.793	0.586 0.559	1.414 1.352
OH-1(TS)	343 1,472	1.304 1.082	0.957 0.777	2.261 1.859
OH-1(MS)	343 1,472	1.525 1.184	1.053 0.823	2.578 2.007
OH-64	343	2.147	0.947	3.094
AS-350	343 1,472	1.103 0.796	1.053 0.828	2.156 1.624
A-129	343 1,472	1.361 1.044	1.053 0.828	2.414 1.872
ASH(2S)(2T)	343 1,472	1.423 1.034	1.053 0.828	2.476 1.862
ASH(1S)	343 1,472	1.108 0.802	1.053 0.828	2.161 1.630

METHODOLOGY

The data base for this study was all OH-58A major and minor aircraft accidents occurring during calendar years 1972 through 1978. The reports of these accidents are in the files of USASC. The accident data used was taken from USASC files and is summarized in table 2. Terms that appear in table 1 and throughout the report are defined in Appendix D.

TABLE 2.—OH-58A Study Baseline

OH-58A Accidents, CY 72-78	133 major 13 minor
Flight Hours	2,235,551
Accident Rate	6.53
Crewmembers Aboard	269
Crewmember Fatalities	34 (12%)
Crewmember Injuries	87 (32%)

The file copies of the "Technical Report of U.S. Army Aircraft Accident" (DA Form 2397-series) for the baseline OH-58A were reviewed. These cases were analyzed on a manual, case-by-case basis placing each of the candidate designs into the same accident situation as the baseline OH-58A. The analysis was broken into two parts: a crashworthiness analysis and a flight safety analysis. These two analyses were performed in parallel by two respective subgroups of the study team (organization in Appendix A). The crashworthiness subgroup essentially answered the question "Given that the accident has occurred, would the occupants have been injured and what would be the material damage?" The flight safety analysis answered the question "Would the accident have occurred at all?"

The crashworthiness analysis provided a mean cost per accident resulting from materiel damage and crewmember injury. Injury cost data was based on DODI 1000.19 and the *Engineering Analysis of Crash Injury in OH-58A Aircraft* (references 4 & 5). The flight safety analysis determined the accident rate. The product of flight hours, accident rate, and cost per accident determines the fleet accident cost for each candidate aircraft. A detailed description of the methodology is provided in Appendix C.

RESULTS AND DISCUSSION

General. This study encompassed both flight safety and crashworthiness design features of the 11 candidate aircraft. The results presented herein address only the homogeneous fleet of 1,472 aircraft. The economic impact of the various HIGH-LOW mixes is presented in a summation in Appendix E.

Baseline Aircraft. The OH-58A was chosen as the baseline aircraft because of similarity in aircraft design and missions of the OH-58A and the proposed ASH. Even though the OH-58A was the closest baseline available, this report will point out several areas of dissimilarity.

The analysis yielded several major conclusions about the OH-58 mishap cause factors. The major cause factors were identified. Of these, the primary cause factor of the accidents was identified as human error. Approximately 80 percent of all the accidents had only human error cause factors. Of the 20 percent of the accidents identified as having materiel failure cause factors, 86 percent had engine failure/malfunctions.

Projected Accident Rate. Accident rate projections (peacetime operations) for each of the candidate aircraft are presented in figure 1. Accident rates are depicted in terms of the number of accidents per 100,000 aircraft flight hours. Superimposed on the accident rate projections are corresponding projections for the attrition rates for each candidate (hardware damage greater than 50 percent).

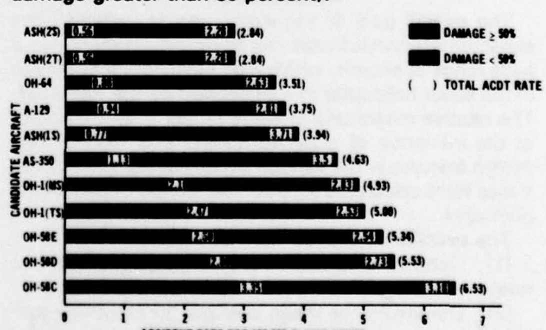

FIGURE 1.—Projected Peacetime Accident Rates for Candidate Aircraft

The accident rate projections vary from a high of 6.53 for the OH-58C to a low of 2.84 for the ASH (2T), (2S). There are a number of specific design features which contributed to the decrease in the projected accident rate from the OH-58C. The two major design features to increase flight safety and reduce the accident rate for the advanced scout mission are the twin engine design of the ASH (2S), (2T), OH-64, and A-129 and the incorporation of wire cutters for the ASH (1S), (2S), (2T). The twin engine designs with contingency power allowing substantial single engine performance had the greatest single influence on accident reduction. The twin engine and wire cutter design features are discussed along with other critical design features below.

Projected Mean Loss Per Accident. The primary objective of crashworthiness improvements is the prevention of crash injury to crewmembers. The need for this improvement is depicted in figure 2 which shows the projected number of casualties for each candidate as a percentage of the total crew on board. The percentages shown include all projected fatal and nonfatal injuries from all causes. These statistics may be considered the probability that a service member will be injured or killed given that he is an occupant in a major or minor aircraft accident occurring to a candidate aircraft. This probability ranges from a high of 44.5 percent for OH-58C to a low of 26.7 percent for the new development (ASH twin and single) aircraft. The smaller figures of the newer aircraft reflect the estimated effectiveness of crashworthiness improvements in these aircraft. The difference between the ASH designs and the OH-64 is the optical relay tube (ORT) in the copilot station of the OH-64. This ORT presents a severe head strike hazard in an accident sequence. The relatively constant fatality rate is a reflection of those nonsurvivable accidents occurring in the baseline aircraft in which the impact forces were beyond human tolerance.

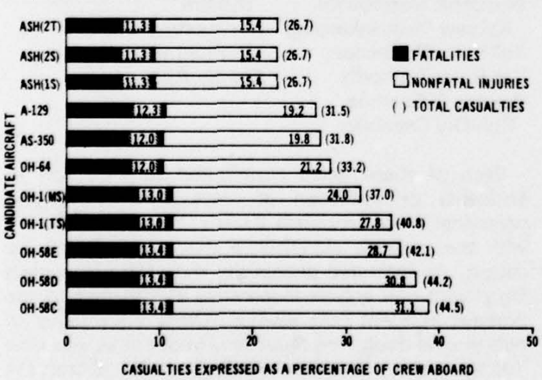

FIGURE 2.—Projected Casualties for Candidate Aircraft

The hardware losses were studied in terms of a percentage of the acquisition costs of both the airframe and the mission equipment. The high cost of mission equipment (up to 50 percent of unit cost) is shown in table 1. The results of hardware losses are reflected in figure 3. The losses depicted in this figure are the mean hardware and mission equipment damages divided by the respective total unit acquisition cost for each candidate. The influence of MIL-STD-1290 crashworthiness improvements (in particular, energy absorbing landing gear, frangible tipped rotor blades, and tail rotor protection) can clearly be seen in the reduction of damage to the hardware. The difference between the OH-58C and the new development aircraft (60% vs. 29%) is a direct result of this increased crashworthiness design. Additionally, the differences shown in damage to mission equipment are primarily dependent upon the location of the target acquisition and designation system (mast-mounted sight vs. nose-mounted sight). Added benefits could be gained in reducing hardware damage cost by careful selection of location and additional protection for all of the mission equipment package.

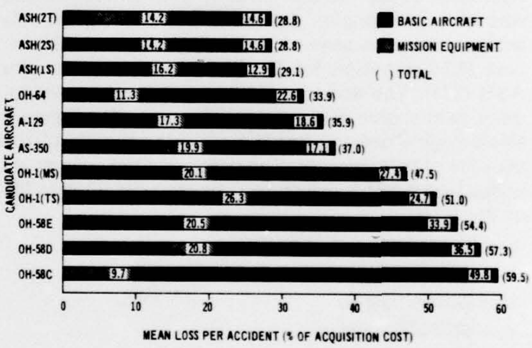

FIGURE 3.—Projected Mean Loss per Accident as a Percentage of Acquisition Cost

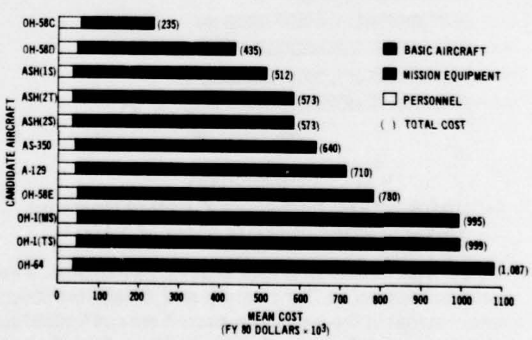

FIGURE 4.—Projected Mean Cost per Accident

Crash injury plus hardware damage both contribute to the projections for the mean loss per accident as shown in figure 4. The projected loss per accident is lowest for the OH-58C ($235K) because of its low-cost airframe and lack of high dollar mission equipment (reference table 1). An interesting fact is the relatively low cost per accident for injury to personnel in all

aircraft. This results from the very conservative costing of DODI 1000.19 (reference 4). From an economic standpoint, these personnel losses are relatively small; however, they may have a large impact on mission effectiveness as discussed below.

Total Accident Losses Over 20-Year Peacetime Operation. The total accident losses for a 20-year peacetime operation of the various candidate aircraft are presented in figure 5. These totals are for a homogeneous fleet of 1,472 candidate aircraft and reflect the influences of both the accident rates and crashworthiness features previously discussed. The OH-58C would be expected to have the lowest life cycle cost at $108.5 million, primarily because of its low airframe acquisition cost and lack of high dollar mission equipment. Of the candidates that are comparable in mission capability and design, the lowest cost was the ASH twin designs ($115 million). This reflects the lower accident rate due to the twin engine design. The OH-64 was more costly ($269.6 million), even though it also was of a twin-engine design and had a comparable accident rate, because of its relatively high acquisition cost ($3.094 million for OH-64 vs. $1.862 million for ASH (2T)). The accident losses for the new development twin engine design versus the new development single engine design provide a suitable estimate of the benefits of twin engines. The difference between these losses was a $27.5 million savings over the 20-year life of the ASH.

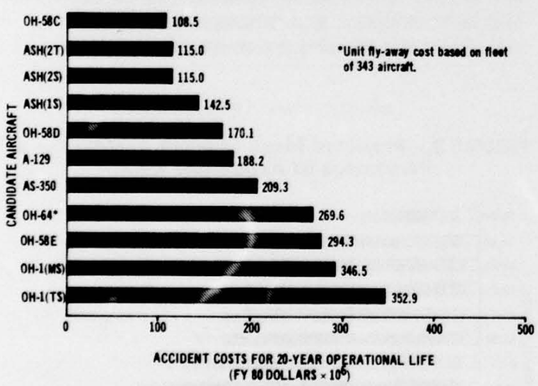

FIGURE 5.—Total Peacetime Accident Costs for 20-Year Operational Life (Fleet of 1,472)

Projected Casualties and Aircraft Attrition. The overall influences of flight safety and crashworthiness improvements in the candidate aircraft are not limited to their economic effects as discussed above. In a time of limited physical assets such as a "come as you are war," the conservation of crewmembers and aircraft will be critical to success. Aircraft and personnel losses may have critical impact on mission effectiveness. Twenty-year projections for these losses are presented in table 3.

These projections are considered to be conservative estimates of the influences of flight safety and crashworthiness under peacetime conditions. They range from a low for the twin ASH designs (39 aircraft and 107 casualties) to a high for the OH-58C (237 aircraft and 411 casualties). These peacetime projections provide an estimate of the *relative* effects on unit readiness and combat staying power under tactical conditions.

TABLE 3.—Projected Casualties and Aircraft Attrition (20-Year Losses)

Candidate	Aircraft Attrition	Casualties Fatalities	Casualties Injuries	Casualties Total
OH-58C	237	123	288	411
OH-58D	198	104	241	345
OH-58E	184	101	217	318
OH-1 (TS)	174	92	196	288
OH-1 (MS)	148	91	167	258
OH-64	62	59	108	167
AS-350	80	79	130	209
A-129	66	65	102	167
ASH (1S)	55	63	86	149
ASH (2S) (2T)	39	45	62	107

Critical Design Features. During the analysis of the individual accidents, design features of each candidate aircraft were assessed as to their accident prevention potential. Critical design features were identified through a qualitative assessment of all the OH-58A baseline accidents taken as a whole (see Appendix C). These beneficial design features were evaluated in the areas of flight safety and crashworthiness and are presented in table 4.

TABLE 4.—Candidate Design Features Critical for Reducing Accidents

Flight Safety	Crash Safety
Twin Engine	Crashworthy Fuel System
Wire Protection	High Mass Item Retention
Wheeled Landing Gear	Crew Seat and Restraint System
Electronic Displays for Aircrew "Housekeeping"	Noninjurious Cockpit Environment
Tail Rotor Protection	Energy Absorption
Tail Rotor Authority	
Bearing & Gearbox Run-Dry Capability	

Each of these items contributed to reduction of accidents or reduction of losses, hardware, and personnel in the candidate aircraft. The design feature with the greatest significance was the twin engine design. As indicated previously, the ability to sustain flight with one engine inoperative contributed to the greatest accident cost savings. Other advantages of twin engine design are reductions in out of service time due to recovery of a downed single engine aircraft (14 hours mean time per mishap—reference 16) or reductions in operational delays and additional assets needed to cover the lost time due to engine failure. Because the twin engine design has the greatest potential benefit in accident prevention, an adjunct analysis was performed on all engine failure mishaps in

OH-58 and OH-6 aircraft during the period CY 1970-1978. This analysis increases the baseline sample population and provides a study of the sensitivity of this finding to aircraft configuration and mission. The analysis is presented in Appendix F. This analysis indicates that a twin engine design would have prevented essentially all of the engine failure accidents and reduced the requirement to recover these aircraft.

Wire cutters were identified as having significant impact on accident reduction. During the analysis it was assumed that the new development (ASH (1S) (2S) (2T)) candidates had wire cutters that protected the windshield, main rotor controls, and forward skids. When compared with aircraft of similar design but without wire strike protection (A-129), it was determined that wire cutters would reduce the accident rate by 15 percent. This reduction in accidents would reduce casualties by 16 percent with a total 20-year cost savings of $25 million. It was concluded that no matter which candidate was chosen for the ASH, provisions for wire strike protection should become an integral part of the design.

Design Areas Requiring Additional Consideration. Areas of high potential for improved prevention of accidents are listed in table 5 and are discussed below.

TABLE 5.—Design Areas Requiring Additional Consideration

☐ Mission equipment protection
☐ Improved human engineering
☐ Improved hover stability
☐ Flight performance computer

In the crashworthiness area, benefits can be gained by providing crash protection for the mission equipment. Accident damage to mission equipment ranged from 51 percent of mission equipment cost in the OH-58D to 32 percent of mission equipment costs in the ASH designs. It was found that basic aircraft crashworthiness (MIL-STD-1290) provides a measurable degree of protection. However, greater protection could be provided in the case of aircraft with mast mounted sights by preventing the main rotor from digging into the terrain. This could be accomplished by improved rollover protection and frangible rotor blade tips in all candidates. Additionally, prevention of fuselage ground contact by improved energy attenuating landing gears and strategic location of the mission equipment packages would also provide further protection.

It has been noted previously that 80 percent of the accidents studied were caused by human error alone (no materiel failure or malfunction). A substantial but unquantified portion of these mishaps were contributed to by poor man/machine integration within the aircraft mission environment. The various ASH candidates incorporated a number of design features increasing the tolerance of the overall system to both materiel failures (e.g., twin engines) and pilot errors (e.g., tail rotors protected from ground strike). However, only very limited advances were evident in the ASH candidates in the area of **eliminating** the human errors causing 80 percent of the accidents. (A notable exception to this is the incorporation of electronic displays for aircrew "housekeeping" functions within the new development aircraft which will provide a substantial reduction in ASH pilot errors by reducing his overall workload.) Based on overall review of the pilot-error accidents, the following results were inferred:

☐ ASH pilot workload under nearly all mission segments will be high and appears to exceed pilot capability for the assumed crew makeup (one pilot and one nonrated observer).

☐ Overall crew station configuration (tandem vs. side-by-side) as well as specific cockpit geometry appears to have a significant but unquantifiable impact on crew workload. Crew station configuration must be considered together with crew makeup in evaluating ASH human engineering design.

☐ Previous detailed studies of ASH man/machine integration (reference 6) do not address all presently identified ASH candidate crew station configurations nor all presently envisioned ASH mission elements. Additional human engineering research addressing these areas in light of the information developed during the present study is needed in order to make significant advances in reducing human error accidents.

CONCLUSIONS

☐ Aircraft accidents have a measurable impact on life cycle costs. The extent of impact is defined by the accident cost projections contained herein.

☐ The greatest single category of cause factors contributing to accident costs is operator error. Approximately 80 percent of all mishaps studied were due solely to pilot error. The underlying cause of a majority of these pilot errors was inadequate integration of the man and the machine within the mission environment.

☐ Incidence of pilot-error accidents is anticipated to remain high with any of the ASH candidates. This finding can be primarily attributed to:

a. Apparent lack of progress in identifying and reducing causes of pilot errors.

b. Anticipated high crew workload with one flight rated and one nonrated crewmember.

☐ The largest single contribution to accident causes in the area of materiel failure or malfunction was the power and propulsion subsystem.

☐ The largest single contribution to personnel injury and hardware damage in the baseline OH-58A (once the accident has occurred) is the inadequate retention of the main rotor and transmission.

☐ Relative to other comparable candidates, the ASH twin designs should have fewer accidents and lower total accident costs. The twin engine designs of these two aircraft provide a clear distinction between these aircraft as a group and the next lower cost candidate, ASH (1S).

☐ The differences in accident costs are the result of

design features which increase the tolerance of the aircraft system to failures. The features resulting in the largest benefits are presented without respect for priority below:

a. Twin engine design with one-engine-inoperative performance.

b. MIL-STD-1290 crashworthiness.

c. Protection against wire strikes.

d. Reduced pilot workload due to crew station configuration and anti-torque system improvements (increased authority and addition of stability augmentation system).

e. Wheeled landing gear.

f. Capability of gearboxes and bearing for prolonged operation after complete loss of lubricant.

☐ Additional features have been identified which, if incorporated, would also result in lower overall accident costs:

a. Improved crash protection for mission equipment electronics.

b. Improved hover-hold capability.

c. On-board performance computer.

RECOMMENDATIONS

☐ Recommend that the results of this study be used in developing rationale and input to future Army and DOD reviews of the ASH.

☐ Recommend that detailed human engineering research, considering the pilot error information developed during the present study, be undertaken in order to identify design approaches to reduce the magnitude of human-error accidents which are anticipated to continue with this aircraft. This research should build on the findings of reference 6 but should be expanded to address all ASH crew station configurations as well as all critical mission scenarios. Sensitivity of single pilot workload to variations in the training, qualifications, and tasks of the second nonrated crewmember should be an important element of this analysis.

☐ Recommend that consideration be given in any Request for Proposal (RFP) to areas having large potential for cost effective savings. These areas are summarized in the last two conclusions above.

☐ Recommend that a follow-on study be performed later in the ASH acquisition process when more complete design information will become available. For greatest usefulness, this follow-on study should be performed as an adjunct to a future government competitive testing and source selection and evaluation of ASH prototype designs.

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APPENDIX A
Organization of Study Group

A 13-man study team performed the required analysis. A wide variety of engineering, human factors, and aircraft operational experience was used. As listed below, representatives from the Army Safety Center (USASC), the Army Aeromedical Research Laboratory (USAARL), the Army Human Engineering Laboratory, (USAHEL), and the Army Applied Technology Laboratory (ATL) participated in the study.

Dr. James E. Hicks (Chairman)
Aerospace Engineer, USASC

MAJ James E. Jenks, Jr.
Aeronautical Engineer, USASC

Mr. Billy H. Adams
Aerospace Engineer, USASC

MAJ Andrew E. Gilewicz
Aeronautical Engineer, USASC

Dr. Mark A. Hoffman
Human Factors Specialist, USAHEL

Mr. G. Dwight Lindsey
Research Psychologist, USASC

CW3 James M. Hooper
Flight Safety Technician, USASC

MAJ George G. Reese, Jr.
Aviation Safety Officer, USASC

Mr. George T. Singley III
Aerospace Engineer, ATL, USARTL

CPT Dennis Shanahan
Flight Surgeon, USAARL

Mr. Laurel D. Sand
Air Safety Specialist, USASC

2LT David Cote
Human Factors Engineer, USAARL

Mr. Tony Mance
Human Factors Specialist, USAHEL

These professionals were organized into two working groups by field of expertise as shown below:

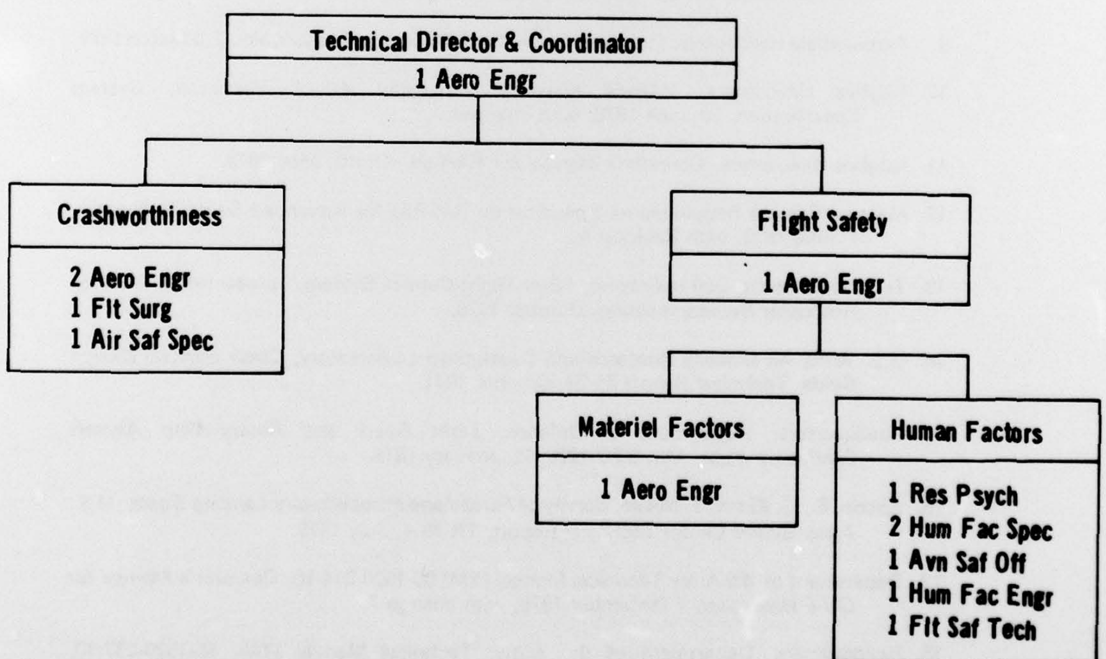

FIGURE A-1.—Study Group Organization

APPENDIX B
Candidate Aircraft Descriptions

Description of the pertinent design features of each candidate aircraft was assembled from technical data from a number of sources listed in the references.

These aircraft descriptions were agreed upon by the ASH Program Manager and USASC before the study. A summary of the descriptive data is contained below and in Table B-1.

ASH (1S)

This is a new development airframe incorporating one advanced technology engine (ATE). Seating arrangement will be side by side. A mast-mounted sight and a nose-mounted pilot's night vision system (PNVS) will be incorporated. Flight control system will be fly-by-wire or fly-by-optics.

The assumption was that the (side-by-side) internal cockpit geometry will be the same as the Aerospatiale AS-350 (see below). Cathode Ray Tube (CRT) displays will be used for all housekeeping functions. The observer's PNVS will have a rubber (frangible) boot to shield the CRT light from the pilot's vision. The pilot's PNVS will be displayed on a helmet mounted display sight system.

ASH (2S)

This is a new development airframe incorporating two ATEs. Seating and internal cockpit geometry will be identical to the ASH (1S).

ASH (2T)

This is a new development airframe incorporating advanced technology engines. Seating arrangement will be tandem. A mast-mounted sight and nose-mounted PNVS will be incorporated. The pilot's PNVS will be displayed on an Integrated Helmet and Display Sighting System (IHADSS). Flight control system will be fly-by-wire or fly-by-optics.

The assumption was that the internal cockpit geometry will be the same as the A-129 (see below). CRT displays will be used for all housekeeping functions. Other assumptions relative to PNVS are identical to other ASH airframes.

OH-1 (TS)

The OH-1 will be a modified Army/Bell Helicopter AH-1S. The following modifications will be incorporated:

(1) Nose mounted TADS/PNVS with the direct-vu-optics (ORT) projecting into the copilot's station, similar to Army/Hughes YAH-64.

(2) Addition of 10 inches to nose for incorporation of TADS/PNVS.

(3) Single T700-GE-401 engine.

(4) Remove all weapons. CRT displays for housekeeping and mission functions will replace weapons armament panels.

(5) Remove wings.

(6) Addition of hub spring to improve control power at reduced load factors.

(7) Multiplex electronics system.

(8) New main rotor gearbox with fourth shaft port.

(9) Crashworthy crew seats with 8-inch stroke.

(10) Transparent blast shield to protect other crewmember during 23mm HEI impact.

(11) Increased ballistic protection for fuel system.

OH-1 (MS)

This is a highly modified AH-1S. The following modifications will be incorporated:

(1) 4-bladed rigid rotor.

(2) Mast-mounted sight system.

(3) Fly by wire/optics (STAR system - reference 13).

(4) T700-GE-401 engine.

(5) Remove all weapons. CRT displays for housekeeping and mission functions will replace weapons armaments panels.

(6) Remove wings.

(7) Add 10-inch nose extension for PNVS. Copilot will have frangible boot to view CRT while pilot will use IHADSS.

(8) Crashworthy seat with 8-inch stroke.

(9) Crew barrier to protect crew during 23mm HEI impact.

(10) Increased ballistic protection for fuel system.

(11) Survivable (wide chord) tail rotor.

(12) New main rotor gearbox case with fourth shaft port.

(13) Multiplex electrical system.

OH-64

This a modified Army/Hughes Helicopters AH-64. The only modification is to remove the weapons and add map display, global positioning system, and automatic target handoff.

AS-350

This is a modified Aerospatiale 350 airframe, with side-by-side seating and clockwise main rotor rotation. The modifications consist of:

(1) New crashworthy fuselage.

(2) New crashworthy landing gear.

(3) Replace 350 tail rotor with fenestron design.

(4) 1000 shaft horsepower ATE.

(5) Crashworthy self-sealing fuel system.

(6) Install dual hydraulics and redundant flight controls.

(7) Install nose-mounted PNVS and mast-mounted sight.

A-129

This is a modified version of the Augusta light anti-tank helicopter with tandem seating being developed for the Italian Army. The modifications consist of:

(1) Remove weapons.

(2) Remove wings.

(3) Add nose-mounted PNVS and mast-mounted sight.

OH-58E

This is a highly modified OH-58C. The modifications are:

(1) 4-bladed rigid rotor (654 MR).
(2) Single ATE.
(3) Mast-mounted sight.
(4) Install 206L-1 tail rotor gearbox.
(5) Reinforce tail boom.
(6) Add stability augmentation system.
(7) Reinforce main rotor pylon restraint.
(8) Redesign tail rotor and vertical/horizontal tail.

OH-58D

This is a modified OH-58C. The modifications are:

(1) Redesign tail rotor.
(2) Install 206L-1 tail rotor gearbox.
(3) Reinforce tail boom.
(4) Add SAS and boost.
(5) Mast-mounted sight.

OH-58C/A

These are standard OH-58 aircraft currently in the Army inventory.

TABLE B-1.— Comparison of Pertinent Design Features of Candidate Aircraft

Design Feature	OH-58A	OH-58C/D	OH-58E	OH-1 (TS)	OH-1 (MS)	OH-64	AS-350	A-129	ASH (1S)	ASH (2S)	ASH (2T)
1. Crashworthiness Design											
a. Landing gear											
(1) Type	Skid	Skid	Skid	Skid	Skid	Wheel	Skid	Wheel	Skid	Skid	Skid
(2) Impact capability (FPS)	12	12	12	12	12	30	20	20	20	20	20
(3) Longitudinal & lateral strength	CAR 6	CAR 6	CAR 6	MIL-S-8698		15° (30 fps) 12° (30 fps)	10° roll 10° pitch	10°R 10°P	10°R 10°P	10°R 10°P	10°R 10°P
b. Fuselage											
(1) Maintain livable volume in 95th percentile survivable crash loading.	No	No	No	No	No	Yes	Yes	90th percentile crash	Yes	Yes	Yes
(2) Withstand fuselage plowing	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
(3) Withstand 15fps longitudinal wall impact w/o pilot injury.	No	No	No	No	No	Yes	Yes	90th %	Yes	Yes	Yes
(4) Transmission tie-down strength.	16Gx, 8Gy 16Gz	13Gx, 6Gy 13Gz	16Gx, 8Gy 16Gz	16Gx, 8Gy 16Gz	20Gx, 20Gy 20Gz	20Gx, 20Gy 20/-10Gz	20Gx, 20Gy 20Gz	16Gx, 15Gy 16Y-8Gz	20Gx, 20Gy 20Gz	20Gx, 20Gy 20Gz	20Gx, 20Gy 20Gz
(5) Engine tie-down strength	16Gx, 8Gy 16Gz	16Gx, 8Gy 16Gz	16Gx, 8Gy 16Gz	15Gx, 5Gy 15Gz	15Gx, 5Gy 15Gz	16Gx, 15Gy 15-10Gz	20Gx, 20Gy 20Gz	18Gx, 18Gy 18Gz	20Gx, 20Gy 20Gz	20Gx, 20Gy 20Gz	20Gx, 20Gy 20Gz
(6) Fuselage roof strength for rollover	No	No	No	No[1]	No[1]	4G	4G	4G	4G	4G	4G
(7) Tail boom design sink speed (fps)	8	8	8	8	8	30	20	20	20	20	20
(8) Wire cutters	No	No	No	No	No	No	No	No	Yes[2]	Yes[2]	Yes[2]
(9) Withstand 100 fps, 5 deg impact with terrain	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
c. Fuel system											
(1) Crashworthy main fuel system	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
(2) Rollover vent valves or equivalent	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
(3) Crashworthy auxiliary fuel system	Yes	Yes	Yes	Yes	Yes	No Jettisonable	Yes	Yes	Yes	Yes	Yes
d. Seating											
Crashworthy crew seats	No	No	No	Yes 8" stroke	Yes	Yes 7.6"	Yes	Yes 8"	Yes	Yes	Yes
2. Rotors											
a. Main											
(1) Frangible tips to reduce load on transmission	No	No	No	No	Yes	Yes	No	Yes	Yes	Yes	Yes
(2) Low crack propagation rate	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
(3) Moderate icing protection	No	No	No	Yes	Yes	Yes	Yes	Yes	Partial (eng & canopy)		

TABLE B-1 continued

Design Feature	OH-58A	OH-58C/D	OH-58E	OH-1 (TS)	OH-1 (MS)	OH-64	AS-350	A-129	ASH (1S)	ASH (2S)	ASH (2T)
(4) -0.5G capability	No	No	Yes	No (Hub restraint)	Yes	Yes	Yes	Yes	Yes	Yes	Yes
(5) 4500 hour fatigue design life	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
b. Tail Rotor											
(1) Simplified flex beam	No	No	No	No	No	No	N/A Fenestron	No	Yes	Yes	Yes
(2) Protected from ground strike	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Partial (low vertical fin & guard)		
(3) Protected from tree strike	No	No	Yes	No	No (tolerant)	Yes	Yes	No	No	No	No
(4) Tolerant to ground strike	No	No	Yes (Ring tail)	No	Yes Survivable ballistically	Yes	Yes	Yes	No	Survivable ballistically	
(5) 4500 hour fatigue design life	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
3. Hydraulic/flight controls											
a. Dual mechanical non-rotating flight controls	Partial (TR on C)	TR	TR	No	N/A	Yes (fly by wire backup)	Partial (TR dual)	Yes (fly by wire backup)	N/A	N/A	N/A
b. Redundant fly-by-light/wire flight controls	N/A	N/A	N/A	N/A	Yes	N/A	N/A	N/A	Yes	Yes	Yes
c. Dual hydraulic systems	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
4. Drivetrain											
a. Transmission & gearbox 30 min, dry run capability	No	No	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
b. Low crack propagation rate	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
c. Self-sealing transmission lub tank & lines	No	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
d. Twin engine powered	No	No	No	No	No	Yes	No	Yes	No	Yes	Yes
5. Fuel system											
a. Suction feed from tank to engine	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
b. Engine fire extinguishing	No	No/Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
6. Maneuverability/ Performance											
a. Aero/Structural limits at mission GW	2.5G 3000#	2.34G 3200#	2.5G 3579#	2.75G 8401#	2.75G 8367#	13542#	5.25 ultimate 3.5 manuever 4802#	7327#	6.13 4.09 5108#	6.03 4.02 5965#	5.98 3.99 6329#
b. One engine inoperative performance at mission GW	No	No	No	No	No	HIGE, OEI at 2000'/70°F emerg power	No	43 kts at 2000'/ 70°F	No	HIGE, OEI at 2000'/70°F emergency power	

[1]Inherent capability provided by pylon & blast barrier.

[2]Windshield, main rotor control and skids protected with the capability to cut 3/8" - 7 strand steel guy wire (15,000 lbs static tensil strength) or 3/4" -18 strand aluminum conductor with 1 steel strand reinforced power cable (15,000 lbs sts).

APPENDIX C
Methodology

Life cycle accident costs were estimated for each ASH candidate by performing a retrospective analysis of Army OH-58A aircraft accidents and assessing the accident prevention features of each candidate design. The overall sequence of analysis is shown in Figure C-1. The total analysis was composed of two parts: a crash safety analysis and a flight safety analysis. These two analyses were performed in parallel by two respective subgroups of the study team. The organization of the team is contained in Appendix A. A preprinted analysis sheet was used to summarize the findings of the two subgroups and to make the analysis of each accident more uniform.

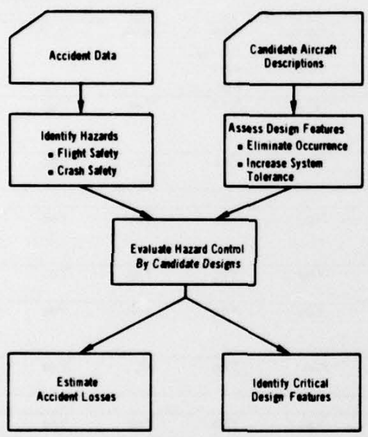

FIGURE C-1.—Overall Sequence of Analysis

Crash Safety Analysis

The crash safety analysis assessed the performance of crashworthiness design features of the candidate aircraft under the same crash conditions experienced in the 136 OH-58A accidents. Crashworthiness was summarized for each candidate by computing a mean loss per accident. This included both hardware damage and personnel injury. Personnel injury losses were computed using the cost figures contained in Department of Defense Instruction 1000.19 (reference 4). To be consistent with other losses, these cost figures were adjusted to FY 80 dollars.

Each individual accident report was studied to identify the causes of injury and hardware damage. The following accident characteristics were studied as a minimum for each accident:

a. Degree of survivability.

b. Impact kinematics.

c. Terrain characteristics and features of the crash sequence.

d. Total OH-58A aircraft damage (component damaged, location, degree of damage).

e. Occupant location in aircraft at time of crash.

f. Occupant injury (type, cause and degree) in the OH-58A.

One member of the crash safety subgroup analyzed each accident report. The result of his analysis, as contained in the completed analysis sheet, was reviewed independently by other team members. The completed summaries thus represent a consensus of opinion. This technique minimized the subjectivity of the results.

Next, hardware damage and personnel injury preventable by the improved technology of each of the candidate aircraft were evaluated relative to that experienced in the OH-58A accidents. During analysis of the losses which would be preventable by improved technology, a conscious effort was made toward conservatism. No benefits were "claimed" unless a reasonably clear-cut case was apparent.

The primary rationale used to determine the benefits of improved crashworthiness is discussed in U.S. Army Air Mobility Research and Development Laboratory Technical Report 71-22. Crashworthiness requirements for new military helicopters are specified in Military Standard 1290. The capabilities/requirements of the candidate aircraft are summarized in Appendix B.

After analysis of all accident reports, the personnel *losses and hardware damages were used to compute* the mean loss per accident for each candidate aircraft. The mean loss per accident was used with results of the accident rate evaluation as discussed below to determine the total loss over the period of operation.

Flight Safety Analysis

Accident rates were established for each of the candidate aircraft by review of the 136 OH-58A accidents and consideration of design features in each candidate which could have prevented the accident. A wide variety of cause factors and design features was *considered. The design features are summarized in* Appendix B. The accident prevention benefits of these design features were determined both for cases in which the system error/failure/malfunction was eliminated in the candidate and cases in which the overall system tolerance to errors/failures/malfunctions was increased. Design features resulting in either improved human engineering or reduced materiel-malfunction-related mishaps were evaluated.

The probability that each cause factor would have been present for each candidate aircraft was estimated. This estimate considered the design features of each aircraft relative to the particular circumstances of the accident being studied. This analysis considered the influences of only those features designed into the candidate aircraft. The myriad of other accident causes, such as improper command supervision in the aviation unit, were considered to apply equally to all candidate aircraft. Consideration of "eliminating" an accident was made only when evidence was available (system specifications, design requirements, etc.) indicating that aircraft design features would lessen the potential for the accident to occur.

During this process each candidate was subjected to the same emergency situation which immediately preceded the OH-58A accident. For accidents following engine failure due to compressor stall, for example, each candidate was placed conceptually into the same flight conditions as the OH-58A with one engine inoperative. For the twin engine aircraft, the probable results were estimated based on the particular flight condition at the time of power loss versus the aircraft performance capabilities with one engine inoperative. For accidents following loss of engine power due to fuel starvation, on the other hand, complete loss of power was uniformly assumed and each candidate aircraft attempted an immediate forced landing.

It should be noted that no judgments were made regarding the suitability of the candidate aircraft to the mission assigned to the OH-58A at the time of its accident. The assumption was made that all aircraft would be equally likely to be performing the mission at hand. For example, for an OH-58A accident occurring during a practice touchdown autorotation, each aircraft was assumed to be equally likely to be performing that training mission and the influence of its own safety features was evaluated from that point onward.

After the percentage estimate was made for all the cause factors in one accident, the cause factors were summed for each candidate aircraft. This sum is a measure of the probability of the accident occurring with the candidate, relative to the baseline OH-58A.

This estimate process was performed by both a human factors and materiel factors team. The teams analyzed each accident independently. Then their findings were consolidated and coordinated. This was to insure that all factors were considered in their proper context and to enhance the objectivity of the analysis by providing a system of checks and balances between the two groups.

This process was repeated for each of the accidents. After all accident reports were analyzed, the cause factor totals were summed to provide a grand total for each candidate aircraft. The candidate grand total represents its probable accident rate relative to the OH-58A experience. This projection for the accident rate was used together with results from the crashworthiness analysis to establish the total fleet losses.

Calculation of Accident Losses Over 20-Year Period

The accident rate and crashworthiness data derived above were used together to establish total accidental losses to be expected over a 20-year period of operation. This was accomplished by first determining the total number of accidents expected during this period by the following:

$$\text{Total Number of Accidents Over 20-Year Period} = \text{Accident Rate of Candidate Aircraft} \times \text{Total Number of Candidate Flying Hours in 20-Year Period Divided by 100,000 Hours}$$

Then the total loss was calculated by

$$\text{Total Loss} = \text{Total Number of Accidents Over 20-year Period} \times \text{Mean Loss Per Accident}$$

The first term on the right hand side of this final equation comes from the accident rate analysis and the second term comes from the crashworthiness evaluation.

Identification of Critical Design Features

After completion of the analysis of all OH-58A accident reports and determination of the potential benefits of candidate design features in each individual accident, a follow-on identification was made of those design features having the greatest accident prevention potential. These critical design features were identified through a qualitative assessment of *all OH-58A accident* reports taken as a whole. Beneficial design features were evaluated in the areas of flight safety and crash safety. Within each of these areas, design features were identified which either (1) prevented a system failure from occurring or (2) increased the overall system tolerance to the failure. After identification of these critical design features, their accident prevention benefits were quantified in one of two ways. First, the benefits of certain design features could be quantified by direct comparison of two or more candidate aircraft which were similar in all respects except for the critical design area under study. Quantification of wire cutter benefits is an example of this approach. Second, other design features were quantified by adjunct studies of a particular candidate assuming variations in the particular design area. Quantification of the benefits of twin-engine design is an example of this approach (Appendix F).

APPENDIX D
Definitions and Terminology

Accident Rate. Computed by dividing the total number of accidents in a given period by the total aircraft flight hours in units of 100,000 hours.

Aircraft Accident. Damage which occurs to one or more aircraft in which flight was intended. Damage as a direct result of hostile fire is not an accident but a combat loss.

Attrition Rate. Computed by dividing the total number of accidents (in which damage ≥ 50%) in a given period by the total aircraft flight hours in units of 100,000 hours.

Crash Force Attenuation. The attenuation of impact forces through the medium of structural deformation. The protective fuselage should deform but not collapse. For example, landing gears should absorb energy "limit loads" prior to failure, and occupant seats must "limit" torso decelerations to non-injurious levels.

Impact Injury. All injury causes other than thermal or drowning.

Major Accident. An OH-58A aircraft accident is classified major when the aircraft is destroyed; damage sustained is in excess of 150 manhours required to remove, repair, and replace damaged components; a major component is destroyed beyond economical repair; or the aircraft is lost or abandoned.

Major Impact. The impact which results in the largest deceleration forces transmitted to the aircraft.

Major Injury. Any injury requiring 5 days of hospitalization or any of the following symptoms without regard to hospitalization:

- ☐ Unconsciousness due to head trauma.
- ☐ Fracture (open or closed) of any bone, other than closed fractures of the phalanges or nasal bones.
- ☐ Traumatic dislocation of any joint, excluding phalanges, or internal derangement of the knee.
- ☐ Injury to any internal organ.
- ☐ Moderate-to-severe lacerations which cause extensive hemorrhage or require extensive surgical repair.
- ☐ Third-degree burns.
- ☐ First- and second-degree burns involving more than 5 percent of the body surface.

Minor Accident. Damage is less than major damage and manhours required to remove, repair, and replace damaged components equals or exceeds 50 manhours.

Nonsurvivable Accident. An accident in which neither of the statements for survivable accidents is satisfied for *all* occupants aboard the aircraft.

Strike Aircraft. Strike aircraft are those aircraft involved in major accidents in which the cost of repair exceeds 50% of the unit acquisition cost.

Survivable Accident. An accident in which both of the following statements are satisfied for all occupants aboard the aircraft:

- ☐ The forces transmitted to the occupant through his seat and restraint system do not exceed the limits of human tolerance to abrupt accelerations.
- ☐ The fuselage structural container maintains a livable volume around the occupant.

Thermal Injury. A fatal or nonfatal injury caused by exposure to combustion effects; heat, noxious gas inhalation, and medical complications caused by thermal burns.

APPENDIX E
Fleet Mix Accident Cost Data

Table E-1 is a summation of the various fleet sizes proposed by the PM-ASH. This table gives the accident rate, mean cost/accident and the 20-year accident cost. The computation of fleet accident rate and cost can be accomplished for any combination of candidates by using the following formulas:

$$\text{20-Year Accident Cost} = \frac{\text{Flight Hours}}{100{,}000} \times \text{Accident Rate} \times \text{Mean Cost/Accident}$$

$$\text{Fleet Accident Rate} = \text{Accident Rate (Candidate A)} \times \frac{\text{Fleet Size, Candidate A}}{1{,}472} + \text{Accident Rate (Candidate B)} \times \frac{\text{Fleet Size, Candidate B}}{1{,}472}$$

TABLE E-1.—ASH Fleet Cost

	Fleet Size	Accident Rate	Mean Cost/ Accident ($10^6)	20-Year Accident Cost ($10^6)
OH-58C	1129		.22818	80.74
	1472	6.53	.235156	108.5
OH-58D	1129		.520206	155.89
	1472	5.53	.435288	170.1
OH-58E	1129		.813639	235.5
	1472	5.34	.780028	294.3
OH-1 (TS)	343		1.205453	99.23
	1472	5.00	.9990402	352.9
OH-1 (MS)	343		1.265865	102.75
	1472	4.93	.994814	346.5
OH-64	343	3.51	1.087130	62.823
AS-350	343		.83474	63.63
	1472	4.63	.639724	209.3
A-129	343		.893772	55.18
	1472	3.75	.710304	188.2
ASH (1S)	343		.684274	43.09
	1472	3.94	.512068	142.5
ASH (2T), (2S)	343		.77471	36.22
	1472	2.84	.573107	115.0

Table F-2 provides for ready comparison of the 20-year accident cost of the primary High-Low mixed fleets as provided by the PM-ASH.

TABLE E-2.—ASH Fleet Mix
(1472 total aircraft)
20-Year Life Cycle Cost ($10^6)

	OH-58C 1129	OH-58D 1129	OH-58E 1129
OH-1 (TS)	179.97	255.12	334.73
OH-1(MS)	183.49	258.64	338.25
OH-64	143.563	218.71	298.323
AS-350	144.37	219.52	299.13
A-129	135.92	211.07	290.68
ASH (1S)	123.83	198.98	278.59
ASH (2S) (2T)	116.96	192.11	271.72

APPENDIX F
Analysis of Engine Failure Mishaps

GENERAL

The present study indicates that, of all the design features in the various ASH candidates, twin engine design has the greatest potential benefit in accident prevention. This finding is based on review of accidents occurring during peacetime operations of one aircraft type (OH-58A). In order to study the sensitivity of this finding to aircraft configuration and mission, an adjunct analysis was performed of all engine failure mishaps occurring to OH-6A and OH-58A aircraft during CY 70-78. This timeframe includes use of these aircraft in both a tactical as well as peacetime environment.

RESULTS AND DISCUSSION

Engine Failures in Tactical Environment. USASC mishap data indicate a total of 91 engine failures occurred in OH-6A and OH-58A aircraft during CY 70-71. A breakdown of engine failures by aircraft type, altitude at emergency, and mishap severity is shown in Table F-1.

TABLE F-1.— OH-6/OH-58 Engine Failure Mishaps, CY 70-71

Altitude at Emergency	OH-6A	OH-58A	Total
Below 300′ AGL			
Forced landing	9	9	18
Accident	15	5	20
Above 300′ AGL			
Forced Landing	15	13	28
Accident	16	0	16
Insufficient Altitude Data			
Forced Landing	6	1	7
All Mishaps	63	28	91

It should be noted that the relatively larger total number of OH-6A engine failures is due to the correspondingly larger number of OH-6A flight hours during this period (engine failures per flight hour were essentially equal).

Table F-1 indicates several overall conclusions. First, of those OH-6A engine failures occurring above 300 feet AGL, approximately one-half resulted in accidents, whereas all OH-58A engine failures at this altitude resulted in forced landings with no damage. This difference is due to (1) more adequate forced landing sites within the typical OH-58A mission scenario during this period and (2) larger inertia of the OH-58A main rotor system insuring that landing sites available could be reached from 300 feet. It should be noted that all of the mishaps due to engine failures above 300 feet are preventable with twin engine design.

Second, Table F-1 indicates that while engine failures below 300 feet AGL potentially result in accident damage for both OH-6A and OH-58A aircraft, the OH-6A engine failure is somewhat more likely to result in accident damage than engine failures in OH-58A. In order to study more closely these mishaps and the reasons for the OH-6/OH-58 differences, mishaps below 300 feet from table F-1 are graphed in figures F-1 and F-2 in terms of the airspeed and altitude at the time of engine failure. Superimposed on figures F-1 and F-2 are the respective avoid/caution areas taken from the aircraft height-velocity (H-V) diagrams of references 7 and 17. Analysis of each aircraft's mishaps relative to its H-V curve essentially factors out the influences of aircraft characteristics (such as rotor inertia) and permits study of the influences of mission environment on mishaps.

Comparison of figures F-1 and F-2 shows that a much larger proportion of the engine failures occurred within the avoid region for the OH-6A than for the OH-58A. Conversely, a higher percentage of the OH-58A engine failures occurred well beyond the caution zone. These differences are the result of different mission scenarios for these two aircraft during this period and appear to be the primary reason for the overall greater potential, discussed above, for an OH-6A engine failure to result in an accident.

Height-velocity curves (one engine inoperative) for the UH-60A and YUH-61A aircraft (taken from references 18 and 19) are also partially depicted in figures F-1 and F-2. Comparison of the OH-6A/OH-58A accident data with these curves indicates that ASH engine failure accidents would be all but eliminated given that the aircraft would be equipped with twin engines of comparable power margin to the UH-60A or YUH-61A.

Engine Failures in Peacetime Environment. USASC mishap files indicate that engine failures resulted in a total of 240 OH-58A mishaps during CY 72-78, as shown in table F-2. Comparable figures for the OH-6A are not shown because of the extremely small number of flight hours during phase-out of this aircraft from the active inventory.

TABLE F-2.—OH-58A Engine Failure Mishaps, CY 70-78

Mishap Severity	CY 70-71	CY 72-78
Forced Landing	23	214
Accident	5 (18%)	26 (11%)
All Mishaps	28	240

The 26 accidents during CY 72-78 were analyzed as part of the main body of the present study and have been discussed previously. The additional information provided by table F-2 indicates that the OH-58A engine failures for the two time periods show little or no difference between the wartime scenario (CY 70-71)

and the peacetime operations (CY 72-78). As discussed earlier, this lack of difference is primarily due to the use of the OH-58A *in Vietnam as a passenger transport* and not as a scout. This passenger mission allowed the pilot to be more selective of his route of flight thereby allowing himself adequate forced landing areas in which to land in case of engine failure. A detailed H-V analysis of the OH-58A engine failures for the period CY 72-78 was not accomplished because of the similarity of the results presented in table F-2.

CONCLUSIONS

Analysis of engine failure mishaps both within the OH-58A and between the OH-58A and the OH-6A provides the following conclusions:

(1) Twin engine design, with one engine inoperative performance, results in substantial accident prevention benefits under all operational environments.

(2) The potential benefits of twin engine design in a tactical environment are extremely sensitive to aircraft configuration and its flight characteristics. This appears to be because these factors influence the mission assigned to the aircraft type and the manner in which the mission is flown in a tactical environment.

(3) Potential benefits of twin engine for scout helicopters may be increased as much as five-fold within a tactical environment due to increased availability of forced landing sites.

(4) Essentially all engine failure induced accidents in OH-6 and OH-58 aircraft during CY 70-78 are preventable with twin engine designs having power margins equivalent to the UH-60A/YUH-61A.

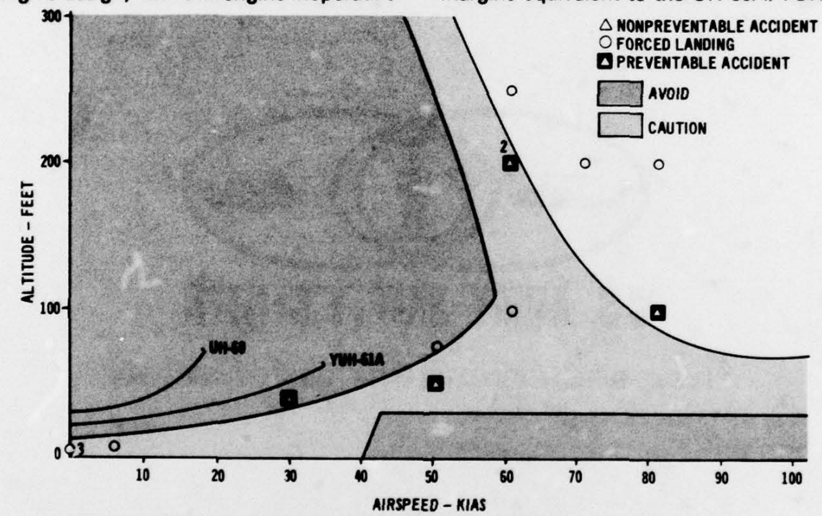

FIGURE F-1.—OH-58A Engine Failures Below 300 Feet AGL, 1970-1972

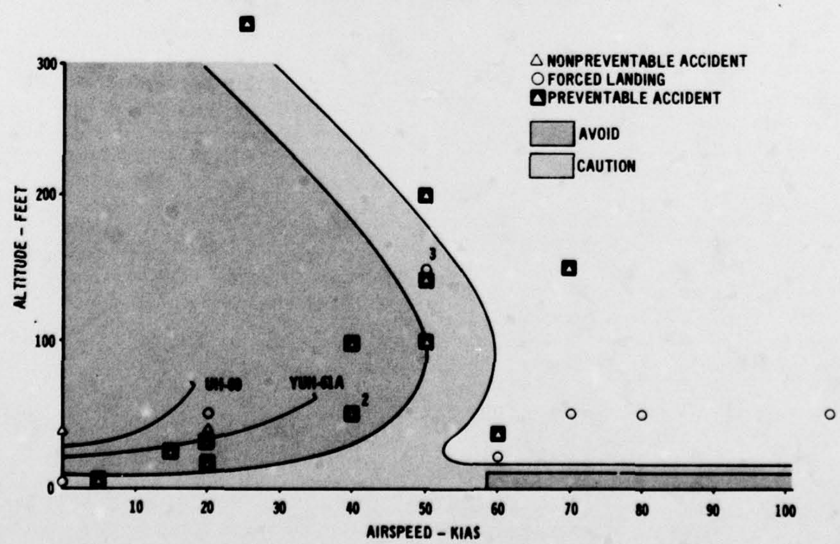

FIGURE F-2.—OH-6A Engine Failures Below 300 Feet AGL, 1970-1972

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